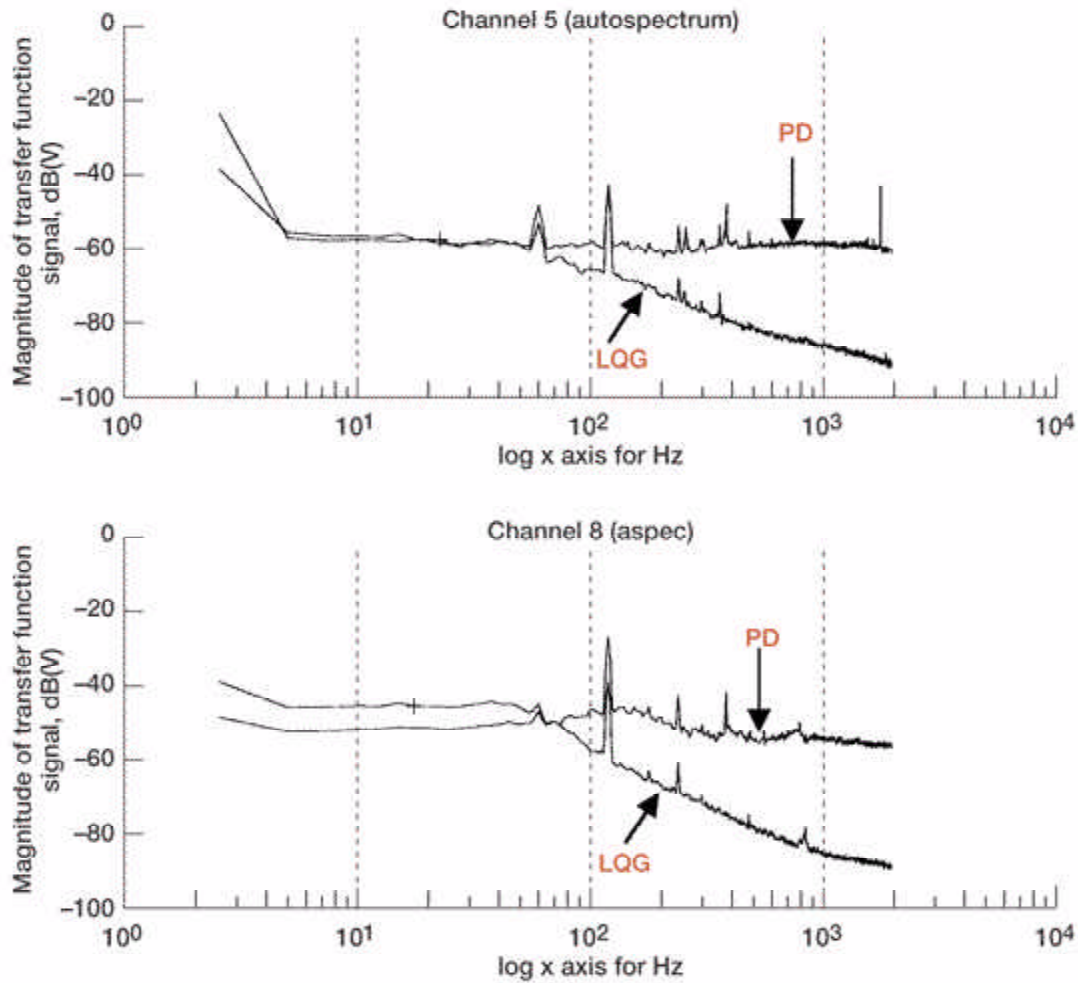
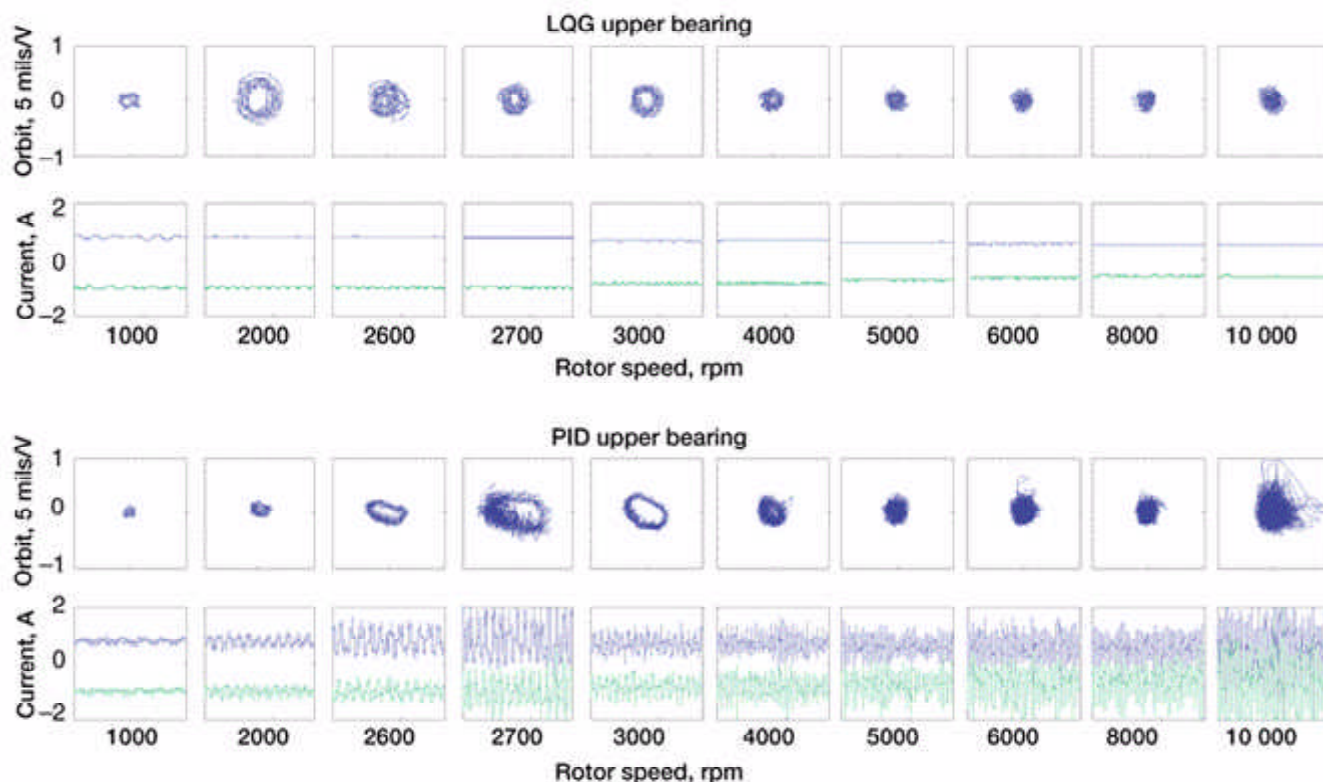


# Optimal Controller Tested for a Magnetically Suspended Five-Axis Dynamic Spin Rig



*Power spectrum of the upper and lower control currents with the PD controller and LQG regulator, respectively.*



*The upper rotor orbits and control currents with the PID controller and LQG regulator.*

NASA Glenn Research Center's Structural Mechanics and Dynamics Branch has developed a fully suspended magnetic bearing system for their Dynamic Spin Rig, which performs vibration tests of turbomachinery blades and components under spinning conditions in a vacuum. Two heteropolar radial magnetic bearings and a thrust magnetic bearing and the associated control system were integrated into the Dynamic Spin Rig to provide magnetic excitation as well as noncontact magnetic suspension of the 35-lb vertical rotor with blades to induce turbomachinery blade vibration (ref. 1).

The new system can provide longer run times at higher speeds and larger vibration amplitudes for rotating blades. Also, it was proven that bearing mechanical life was substantially extended and flexibility was increased in the excitation orientation (direction and phasing).

The first controller we tested for the rotor magnetic suspension was a decentralized proportional-integral-derivative (PID) controller because it was easy to implement. A simple PID controller was sufficient to suppress the vibration amplitude at critical modes. The PID controller had a relatively large control current with high-frequency noise that frequently caused power amplifier and coil burnouts.

Looking for more vibration amplitude suppression and stable rotor orbits at critical modes, we tested a centralized modal controller, which can inherently control critical modes, including bouncing and tilting modes. The rotor orbit over the operating range was reduced by approximately 20 percent, but control current and noise level remained almost

the same as for the proportional derivative (PD) controller.

Next, we tested a control force integral feedback, where the control force was integrated over time slowly and added to the feedback force output until the time-averaged control force became zero (ref. 2). The test results showed better rotor orbit and control current, but the high-frequency noise level that is crucial to good experimental damping test results still remained.

All the controllers worked well in terms of the rotor orbit (position control) and control current level throughout the operating range up to 10 000 rpm. However, we needed to reduce the high-frequency magnetic bearing control noise, which may couple into the blade vibration measuring circuits and provide poor experimental damping test results. Consequently, we tested a linear quadratic gaussian (LQG) regulator that was developed on the basis of a simple second-order experimental plant model that approximates the rotor and magnetic bearing system. The test results showed that in comparison to the PID controller, the LQG controller reduced rotor orbit by about 50 percent. In addition, it significantly reduced the high-frequency control noise level throughout the operating range (see the preceding graph). Finally, clean rotor orbits and lower control current were achieved over the operating range (see the following figure). Thus, the LQG controller was the best controller to use for damping tests on the new magnetically suspended five-axis Dynamic Spin Rig.

## References

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